METAL OXIDE NANOPARTICLE RESISTS WITH SUBSTITUTED BENZOIC ACID LIGANDS

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INTRODUCTION

◆Moore's Law: The number transistors in a dense integrated circuit doubles approximately every two years.

◆ According to Rayleigh Criterion $R = \frac{k_1 \lambda}{NA}$, further pattern reduction depends on deep UV(248nm) and EUV(13.5nm).

◆ Next generation of resist requires higher sensitivity, higher etch resistance and promising chemical stability.

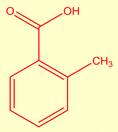
SOLUTION & APPROACH

◆ Extreme ultraviolet lithography (EUVL) :
EUV – shorter wavelength gives higher resolution.

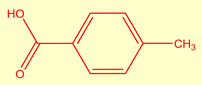
◆ Hybrid nanoparticles with "core-shell" system:

Core materials: ZrO_2 and HfO_2

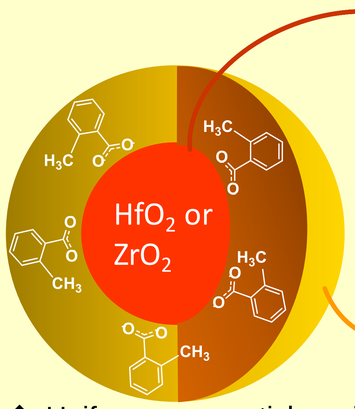
Organic ligand:



2-methylbenzoic acid
(O-toluic acid)



4-methylbenzoic acid
(P-toluic acid)



Inorganic core:
High etch resistance,
Thermal stability
High refractive index

Organic ligand:
Miscible with
PGMEA and other
common coating
solvent

◆ Uniform nanoparticles with size of 2.5-4nm can be obtained(Fig.1).

◆Organic content in the system indicates the ligand content (Fig. 2).

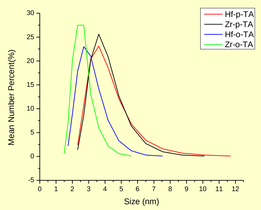


Fig. 1

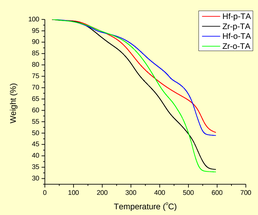
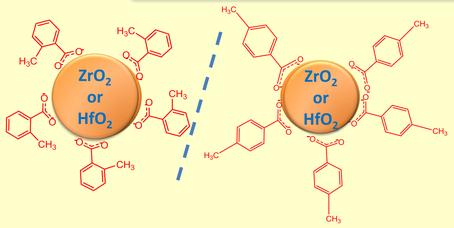


Fig. 2

RESIST CONTENT



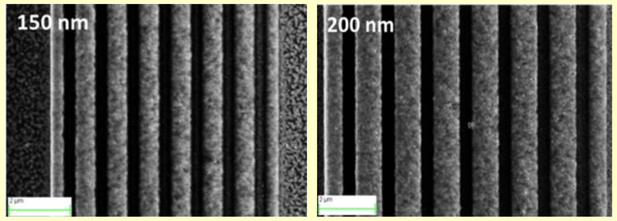
Resist :
ZrO_2-O-toluic acid
HfO_2-O-toluic acid

ZrO_2-p-toluic acid
HfO_2-p-toluic acid

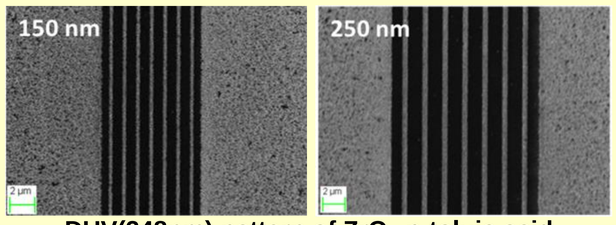
6wt% nanoparticle dispersed in PGMEA/2-butanone
3wt% Photoactive compound :
Photoacid generator (PAG) (*N*-hydroxynaphthalimide triflate)

RESULTS

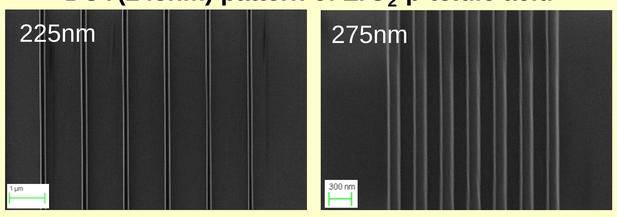
DUV(248nm) pattern of ZrO_2-o-toluic acid



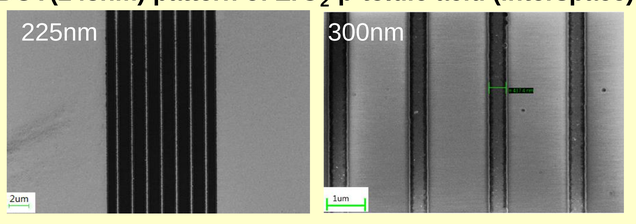
DUV(248nm) pattern of HfO_2-o-toluic acid



DUV(248nm) pattern of ZrO_2-p-toluic acid

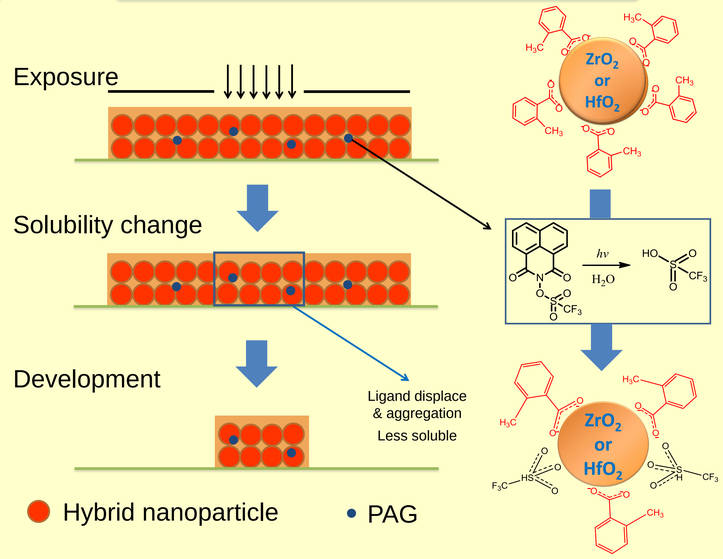


DUV(248nm) pattern of ZrO_2-p-toluic acid (interspace)



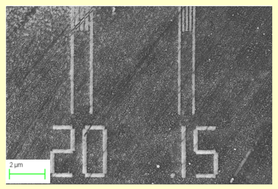
All the DUV patterns are obtained with 3wt% PAG and 150mJ/cm_2 stepper exposure.
Organic developer: 4-methyl-2-pentanol

PATTERNING SCHEME



Ligand exchange mechanism: solubility switch after the ligands formulation changed, dictated by acid strength (pKa).
Common developers:
4-metyl-2-pentanol, PGMEA, o-xylene, 2-butanone, 2-heptanone

EBEAM PATTERNS



HfO_2-O-toluic acid + O-toluic acid
Organic content: 60%
5wt% PAG
Dose: 80μc/cm_2

CONCLUSIONS

- New nanoparticle photoresist formulations with substituted benzoic acid ligands work well with optimized conditions based on binding energy and ligand exchange efficiency.
- 150nm resolution can be achieved with DUV(248nm) exposure, which is the resolution limit of the stepper.
- The ideal roughness and resolution predict the potential to be further examined by EUV lithography.
- Versatile system: tunable by changing core and ligands

ACKNOWLEDGEMENT

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SEMATECH
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